A Demonstration Experiment to Study the Effects of Spacecraft Vibrations on Thermal Diffusion

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A fundamental and intrinsic objective of a microgravity experiment, especially a crystal growth or materials processing experiment, is to obtain diffusion limited growth conditions. Experiments pertaining to crystal growth from melts tend to be especially susceptible to the spacecraft acceleration environment, generally referred to as g-jitter, and great care has to be exercised in minimizing its deleterious effects. The objective of this investigation was to develop a simple scientific experiment that would provide a rigorous experimental basis for assessing the actual influence of jitter on thermal buoyancy driven convection. It employed very simple geometry, in a well understood circumstance, to allow materials science investigators to verify analytical and numerical models currently utilized for design and theoretical studies in a wide range of experiments. Its design, build, testing and integration was achieved in a record 5 months duration using essentially off-the-shelf components and minimal costs.

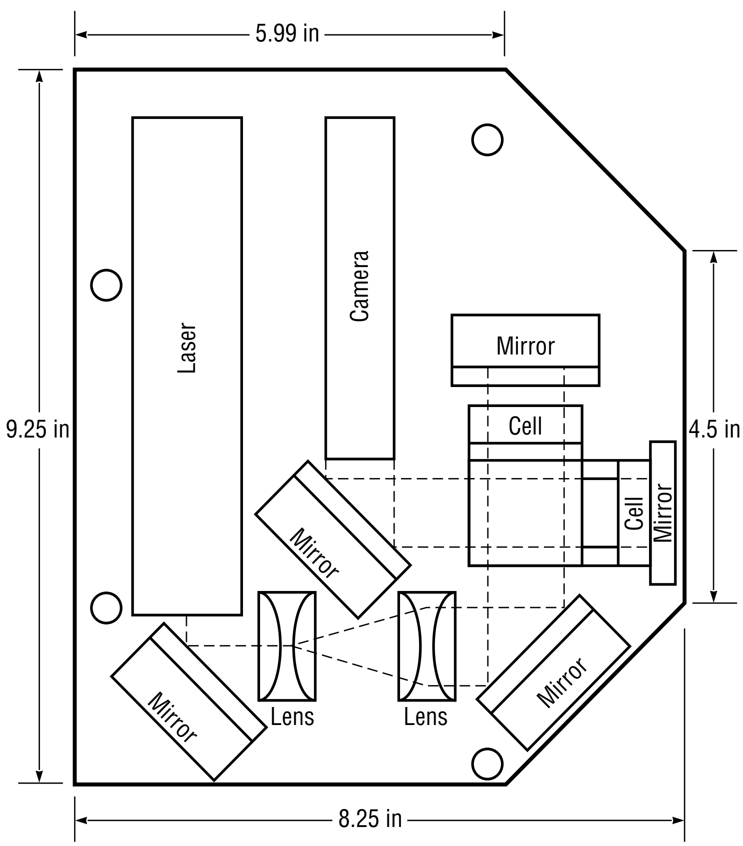

FIGURE 126.—Schematic representation of the Michelson Interferometric system showing component layout adapted to fit STABLE space constraints.

A schematic diagram of the experiment called “Chuck” is shown in figure 126. As the figure shows, the entire unit is compact so that it could be integrated with the STABLE (suppression of transient events by levitation) vibration isolation platform that flew on the United States Microgravity Laboratory–2 (USML–2) mission in October 1995. The unit was designed to be modular and flexible so that not only different optical diagnostic configurations could be easily realized for studying different scientific phenomena, but also the unit could easily fit into the middeck/Space Station gloveboxes or the Canadian microgravity isolation mount (MIM). Figure 126 shows two cell locations, one of which is the experiment cell and the other is the optical path compensating cell used in the Michelson interferometer configuration. The test cell consisted of an optical quality glass cell (4 cm by 4 cm by 1 cm), pre-filled with 0.8 halocarbon oil, and outfitted with a uniform heat flux surface at the bottom of the cell (length 1.3 cm). At activation, power is applied to the heater. The progress and profile the thermal front is monitored by a combination of thermistors and the optical interferometric system and the temperatures, interferograms and acceleration data are recorded for future analysis. The experiment time line is about 15 min at a power level of 0.5 to 1 W followed by a sufficiently long cooling time (45 min) between runs. Due to the fairly quick system response, four different experiment runs were planned and executed; two runs without vibration isolation (hard mounted so that the experiment was subjected to the spacecraft acceleration environment) and two runs with active vibration isolation. Figure 127 shows a comparison of the interferometric fringe behavior from the experiment in space and on Earth. In the terrestrial experiment, Earth’s gravity causes thermal buoyancy driven convection, seen in the figure as rising thermal plumes or blobs. This behavior is absent in the low-gravity experiment.

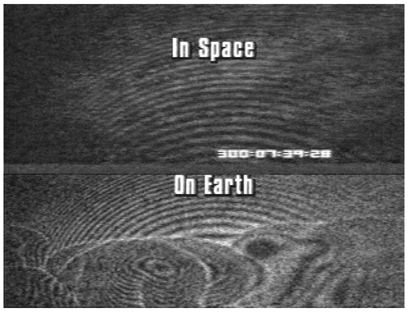

FIGURE 127.—Interferograms from "Chuck" operation in space and on Earth. Note the marked contrast between the two runs and the presence of convective plumes in the ground experiment.

"Chuck" was a unique experiment that was simple, modular and showed that a rugged flight science instrument could be built in a very short time with relatively minimal cost using essentially off-the-shelf components. It is a high-resolution interferometric system that can be used for optical diagnostics (to obtain qualitative and quantitative information) of different scientific phenomena. It contributed advanced design data on optics investigations (such as protein crystal growth) through the early solution of several engineering problems relating to the application of laser diodes and optics to small flight experiments.

[1]Ramachandran, N.; Baugher, C.R.; Rogers, J.; Peters, P.; Roark, W.; Pearcy, G.: "Thermal Diffusion Experiment 'Chuck'—Payload of STABLE." Proceedings of SPIE conference on Space Processing of Materials, Denver, CO, Aug. 4–9, 1996. Ed. N. Ramachandran, pp. 367–378.

[2]Edberg, D.; Boucher, R.; Schenck, D.; Nurre, G.; Whorton, M.; Kim, Y.; Alhorn, D.: "Results of the STABLE Vibration Isolation Flight Experiment." 19th Annual AAS Guidance and Control Conference, Brekenridge, CO, Feb. 7–11, 1996, AAS 96–071.

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Biographical Sketch: Charles Baugher is a materials scientist and deputy division chief in the Microgravity Science and Applications Division of Space Sciences Laboratory. His recent research has been in the area of defining the low-level acceleration environment of the Space Shuttle during microgravity experimentation and in studying effects of that environment on materials processing. He has been published in the areas of electromagnetic propagation in plasmas, the interactions of plasmas with spacecraft, astronomical observations in the infrared, and the morphology of the Earth's magnetosphere.